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(54) System and method of providing MEMS device with anti-stiction coating

(57) In various embodiments of the invention, an anti-stiction coating 160, 170 is formed on at least one surface of an interior cavity of a MEMS device 80. Particular embodiments provide an anti-stiction coating 160, 170 on one or more mirror surfaces of an interferometric light modulation device (iMoD). In other embodiments, an interferometric light modulation device is encapsulated within a package and the anti-stiction coating 160, 170 is applied after the package is fabricated. In one embodiment, one or more orifices are defined in the package, e.g., in a seal, a substrate or a backplate and the anti-stiction coating material is supplied into the interior of the package via the orifice(s). In one embodiment, the anti-stiction coating material includes a self-aligned (or self-assembled) monolayer. In yet another embodiment, the anti-stiction layer coating can be incorporated into a release process where a sacrificial layer of an interferometric light modulation device is etched away with the use of a gas.

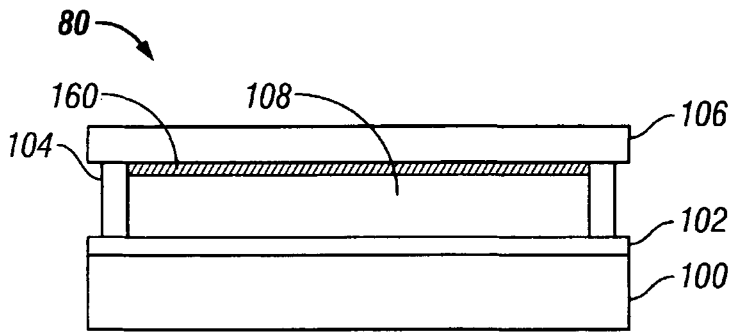

FIG. 11A

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Description

Background

[0001] The field of the invention relates to micro-electro-mechanical (MEMS) systems. More specifically, the invention relates to systems and methods of providing an anti-stiction coating in a MEMS device, including an interferometric light modulator.

[0002] MEMS include micro mechanical elements, actuators, and electronics. Micromechanical elements may be created using deposition, etching, and or other micromachining processes that etch away parts of substrates and/or deposited material layers or that add layers to form electrical and electromechanical devices.

[0003] Spatial light modulators are an example of MEMS systems. Spatial light modulators used for imaging applications come in many different forms. Transmissive liquid crystal device (LCD) modulators modulate light by controlling the twist and/or alignment of crystalline materials to block or pass light. Reflective spatial light modulators exploit various physical effects to control the amount of light reflected to the imaging surface. Examples of such reflective modulators include reflective LCDs, and digital micromirror devices (DMD™).

[0004] Another example of a spatial light modulator is an interferometric modulator that modulates light by interference. An interferometric modulator may comprise a pair of conductive plates, one or both of which may be transparent and/or reflective in whole or part and capable of relative motion upon application of an appropriate electrical signal. One plate may comprise a stationary or fixed layer deposited on a substrate, the other plate may comprise a metallic membrane separated from the stationary layer by an air gap. Such devices have a wide range of applications, and it would be beneficial in the art to utilize and/or modify the characteristics of these types of devices so that their features can be exploited in improving existing products and creating new products that have not yet been developed. An iMoD™ is one example of an interferometric light modulator. The iMoD employs a cavity having at least one movable or deflectable wall. As the wall, typically comprised at least partly of metal, moves towards a front surface of the cavity, interference occurs that affects the color of light viewed by a user.

Summary

[0005] The system, method, and devices of the invention each have several aspects, no single one of which is solely responsible for its desirable attributes. Without limiting the scope of this invention, its more prominent features will now be discussed briefly. After considering this discussion, and particularly after reading the section entitled "Detailed Description of Certain Embodiments" one will understand how the features of this invention provide advantages over other display devices.

[0006] In various embodiments of the invention, an anti-stiction coating is provided on at least one surface of a MEMS device in order to reduce attractive forces between the at least one surface and other surfaces of the MEMS device. More specifically, in certain embodiments, the anti-stiction coating is provided on at least one surface on an interior portion of an interferometric light modulating cavity. This interior portion with the anti-stiction coating may be a reflective element, such as a mirror, a transmissive element, such as a transparent substrate, or another layer on said reflective element or transmissive element.

[0007] In one embodiment, an interferometric light modulating device is provided, said device comprising: a reflective element; a transmissive element; and an anti-stiction coating located between at least a portion of said reflective element and said transmissive element.

[0008] In another embodiment, a method for manufacturing an interferometric light modulating device is provided, said method comprising: providing a transmissive element; providing a reflective element; and providing an anti-stiction coating, wherein said anti-stiction coating is located between at least a portion of said reflective element and said transmissive element.

[0009] In another embodiment, an interferometric light modulating device is provided, said device comprising: reflective means for reflecting light; transmissive means for transmitting light therethrough; modulating means for modulating light transmitted through said transmissive means; and means for reducing attractive forces between said reflective means and said transmissive means.

[0010] In another embodiment, an interferometric light modulating device is provided by a method of manufacturing, said method comprising: providing a reflective element; providing a transmissive element; and providing an anti-stiction coating, wherein said anti-stiction coating is located between at least a portion of said reflective element and said transmissive element.

Brief Description of the Drawings

[0011]

Figure 1 is an isometric view depicting a portion of one embodiment of an interferometric modulator display in which a movable reflective layer of a first interferometric modulator is in a released position and a movable reflective layer of a second interferometric modulator is in an actuated position.

Figure 2 is a system block diagram illustrating one embodiment of an electronic device incorporating a 3x3 interferometric modulator display.

Figure 3 is a diagram of movable mirror position versus applied voltage for one exemplary embodiment of an interferometric modulator of Figure 1.

Figure 4 is an illustration of a set of row and column voltages that may be used to drive an interferometric modulator display.

Figures 5A and 5B illustrate one exemplary timing diagram for row and column signals that may be used to write a frame of display data to the 3x3 interferometric modulator display of Figure 2.

Figure 6A is a cross section of the device of Figure 1.

Figure 6B is a cross section of an alternative embodiment of an interferometric modulator.

Figure 6C is a cross section of another alternative embodiment of an interferometric modulator.

Figures 7A-7C are schematic views of a basic package structure for an interferometric modulator.

Figure 8 is a detailed side view of an interferometric light modulator.

Figure 9 illustrates an interferometric modulator coated with anti-stiction material according to one embodiment of the invention.

Figure 10 illustrates an interferometric modulator coated with anti-stiction material according to another embodiment of the invention.

Figures 11A, 11B, and 11C illustrate an interferometric modulator coated with anti-stiction material according to another embodiment of the invention.

Figures 12A and 12B illustrate an interferometric modulator coated with anti-stiction material according to still another embodiment of the invention.

Figure 13 illustrates an anti-stiction layer coating system for an interferometric modulator according to one embodiment of the invention.

Figure 14 is a flow chart of a method of providing an anti-stiction coating to a MEMS device according to one embodiment of the invention.

Figure 15 is a flow chart of a method of providing an anti-stiction coating to an interferometric light modulating device according to one embodiment of the invention.

Figures 16A and 16B are system block diagrams illustrating an embodiment of a visual display device comprising a plurality of interferometric modulators.

Detailed Description of the Preferred Embodiments

[0012] In various embodiments of the invention, an anti-stiction coating is formed on at least one surface of an interior cavity of a MEMS device. Stiction occurs when surface adhesion forces are higher than the mechanical restoring force of the micro-structure. One purpose of the anti-stiction coating is to prevent two movable layers of the device from sticking together. Particular embodiments provide an anti-stiction coating on one or more mirror surfaces of an interferometric light modulation device, also known as an iMoD. In some embodiments, theanti-stiction coating material includes a self-aligned (or self-assembled) monolayer.

[0013] In various embodiments, an interferometric light modulation device is encapsulated within a package and the anti-stiction coating is applied to the device after the package is fabricated. In one embodiment, one or more orifices are defined in the package, e.g., in a seal, a substrate or a backplate and the anti-stiction coating material is supplied into the interior of the package via the orifice (s).

[0014] In another embodiment, the anti-stiction coating can be incorporated into a release process wherein a sacrificial layer of an interferometric light modulation device is etched away with the use of a gas, such as XeF_2. For example, a mixture of the anti-stiction coating material and XeF_2 may be pumped into a chamber within the device. The chemistry of self aligning monolayers is generally compatible with XeF_2 and can be made to be co-existing processes in the same chamber. In another embodiment, the anti-stiction coating can be applied after the XeF_2 etching is complete.

[0015] In yet another embodiment, the anti-stiction coating may be applied to the sacrificial layer prior to an etching process. In one embodiment, sacrificial material is located within the interior cavity of the interferometric light modulating device. After the anti-stiction coating is applied to the sacrificial layer, another surface within the cavity comes in contact with the sacrificial layer, thereby coating at least a portion of the other surface. The sacrificial layer may then be etched away leaving at least a portion of the other surface with an anti-stiction coating. In some embodiments, the other surface may be a reflective surface such as a mirror, a transmissive surface such as a substrate, or another layer upon one or more of the reflective or transmissive surfaces.

[0016] The following detailed description is directed to certain specific embodiments of the invention. However, the invention can be embodied in a multitude of different ways. In this description, reference is made to the drawings wherein like parts are designated with like numerals throughout. As will be apparent from the following description, the invention may be implemented in any device that is configured to display an image, whether in motion (e.g., video) or stationary (e.g., still image), and whether textual or pictorial. More particularly, it is contemplated that the invention may be implemented in or associated with a variety of electronic devices such as, but not limited to, mobile telephones, wireless devices, personal data assistants (PDAs), hand-held or portable computers, GPS receivers/navigators, cameras, MP3 players, camcorders, game consoles, wrist watches, clocks, calculators, television monitors, flat panel displays, computer monitors, auto displays (e.g., odometer display, etc.), cockpit controls and/or displays, display of camera views (e.g., display of a rear view camera in a vehicle), electronic photographs, electronic billboards or signs, projectors, architectural structures, packaging, and aesthetic structures (e.g., display of images on a piece of jewelry). MEMS devices of similar structure to those described herein can also be used in non-display applications such as in electronic switching devices.

[0017] One interferometric modulator display embodiment comprising an interferometric MEMS display element is illustrated in Figure 1. In these devices, the pixels are in either a bright or dark state. In the bright ("on" or "open") state, the display element reflects a large portion of incident visible light to a user. When in the dark ("off' or "closed") state, the display element reflects little incident visible light to the user. Depending on the embodiment, the light reflectance properties of the "on" and "off" states may be reversed. MEMS pixels can be configured to reflect predominantly at selected colors, allowing for a color display in addition to black and white.

[0018] Figure 1 is an isometric view depicting two adjacent pixels in a series of pixels of a visual display, wherein each pixel comprises a MEMS interferometric modulator. In some embodiments, an interferometric modulator display comprises a row/column array of these interferometric modulators. Each interferometric modulator includes a pair of reflective layers positioned at a variable and controllable distance from each other to form a resonant optical cavity with at least one variable dimension. In one embodiment, one of the reflective layers may be moved between two positions. In the first position, referred to herein as the released state, the movable layer is positioned at a relatively large distance from a fixed partially reflective layer. In the second position, the movable layer is positioned more closely adjacent to the partially reflective layer. Incident light that reflects from the two layers interferes constructively or destructively depending on the position of the movable reflective layer, producing either an overall reflective or non-reflective state for each pixel.

[0019] The depicted portion of the pixel array in Figure 1 includes two adjacent interferometric modulators 12a and 12b. In the interferometric modulator 12a on the left, a movable and highly reflective layer 14a is illustrated in a released position at a predetermined distance from a fixed partially reflective layer 16a. In the interferometric modulator 12b on the right, the movable highly reflective layer 14b is illustrated in an actuated position adjacent to the fixed partially reflective layer 16b.

[0020] The fixed layers 16a, 16b are electrically conductive, partially transparent and partially reflective, and may be fabricated, for example, by depositing one or more layers each of chromium and indium-tin-oxide onto a transparent substrate 20. The transparent substrate 20 may be any transparent substance capable of having a thin film or MEMS device built upon it. Such transparent substances include, but are not limited to, glass, plastic, and transparent polymers. The layers deposited on the substrate 20 are patterned into parallel strips, and may form row electrodes in a display device as described further below. The movable layers 14a, 14b may be formed as a series of parallel strips of a deposited metal layer or layers (orthogonal to the row electrodes 16a, 16b) deposited on top of posts 18 and an intervening sacrificial material deposited between the posts 18. When the sacrificial material is etched away, the deformable metal layers are separated from the fixed metal layers by a defined air gap 19. A highly conductive and reflective material such as aluminum may be used for the deformable layers, and these strips may form column electrodes in a display device.

[0021] With no applied voltage, the cavity 19 remains between the layers 14a, 16a and the deformable layer is in a mechanically relaxed state as illustrated by the pixel 12a in Figure 1. However, when a potential difference is applied to a selected row and column, the capacitor formed at the intersection of the row and column electrodes at the corresponding pixel becomes charged, and electrostatic forces pull the electrodes together. If the voltage is high enough, the movable layer is deformed and is forced against the fixed layer (a dielectric material which is not illustrated in this Figure may be deposited on the fixed layer to prevent shorting and control the separation distance) as illustrated by the pixel 12b on the right in Figure 1. The behavior is the same regardless of the polarity of the applied potential difference. In this way, row/column actuation that can control the reflective vs. non-reflective pixel states is analogous in many ways to that used in conventional LCD and other display technologies.

[0022] Figures 2 through 5 illustrate one exemplary process and system for using an array of interferometric modulators in a display application. Figure 2 is a system block diagram illustrating one embodiment of an electronic device that may incorporate aspects of the invention. In the exemplary embodiment, the electronic device includes a processor 21 which may be any general purpose single- or multi-chip microprocessor such as an ARM, Pentium®, Pentium II®, Pentium III®, Pentium IV®, Pentium® Pro, an 8051, a MIPS®, a Power PC®, an ALPHA®, or any special purpose microprocessor such as a digital signal processor, microcontroller, or a programmable gate array. As is conventional in the art, the processor 21 may be configured to execute one or more software modules. In addition to executing an operating system, the processor may be configured to execute one or more software applications, including a web browser, a telephone application, an email program, or any other software application.

[0023] In one embodiment, the processor 21 is also configured to communicate with an array controller 22. In one embodiment, the array controller 22 includes a row driver circuit 24 and a column driver circuit 26 that provide signals to a pixel array 30. The cross section of the array illustrated in Figure 1 is shown by the lines 1-1 in Figure 2. For MEMS interferometric modulators, the row/column actuation protocol may take advantage of a hysteresis property of these devices illustrated in Figure 3. It may require, for example, a 10 volt potential difference to cause a movable layer to deform from the released state to the actuated state. However, when the voltage is reduced from that value, the movable layer maintains its state as the voltage drops back below 10 volts. In the exemplary embodiment of Figure 3, the movable layer does not release completely until the voltage drops below 2 volts. There is thus a range of voltage, about 3 to 7 V in the example illustrated in Figure 3, where there exists a window of applied voltage within which the device is stable in either the released or actuated state. This is referred to herein as the "hysteresis window" or "stability window." For a display array having the hysteresis characteristics of Figure 3, the row/column actuation protocol can be designed such that during row strobing, pixels in the strobed row that are to be actuated are exposed to a voltage difference of about 10 volts, and pixels that are to be released are exposed to a voltage difference of close to zero volts. After the strobe, the pixels are exposed to a steady state voltage difference of about 5 volts such that they remain in whatever state the row strobe put them in. After being written, each pixel sees a potential difference within the "stability window" of 3-7 volts in this example. This feature makes the pixel design illustrated in Figure 1 stable under the same applied voltage conditions in either an actuated or released pre-existing state. Since each pixel of the interferometric modulator, whether in the actuated or released state, is essentially a capacitor formed by the fixed and moving reflective layers, this stable state can be held at a voltage within the hysteresis window with almost no power dissipation. Essentially no current flows into the pixel if the applied potential is fixed.

[0024] In typical applications, a display frame may be created by asserting the set of column electrodes in accordance with the desired set of actuated pixels in the first row. A row pulse is then applied to the row 1 electrode, actuating the pixels corresponding to the asserted column lines. The asserted set of column electrodes is then changed to correspond to the desired set of actuated pixels in the second row. A pulse is then applied to the row 2 electrode, actuating the appropriate pixels in row 2 in accordance with the asserted column electrodes. The row 1 pixels are unaffected by the row 2 pulse, and remain in the state they were set to during the row 1 pulse. This may be repeated for the entire series of rows in a sequential fashion to produce the frame. Generally, the frames are refreshed and/or updated with new display data by continually repeating this process at some desired number of frames per second. A wide variety of protocols for driving row and column electrodes of pixel arrays to produce display frames are also well known and may be used in conjunction with the present invention.

[0025] Figures 4 and 5 illustrate one possible actuation protocol for creating a display frame on the 3x3 array of Figure 2. Figure 4 illustrates a possible set of column and row voltage levels that may be used for pixels exhibiting the hysteresis curves of Figure 3. In the Figure 4 embodiment, actuating a pixel involves setting the appropriate column to-Vbias, and the appropriate row to +ΔV, which may correspond to -5 volts and +5 volts respectively Releasing the pixel is accomplished by setting the appropriate column to +Vbias, and the appropriate row to the same +ΔV, producing a zero volt potential difference across the pixel. In those rows where the row voltage is held at zero volts, the pixels are stable in whatever state they were originally in, regardless of whether the column is at +Vbias, or-Vbias. As is also illustrated in Figure 4, it will be appreciated that voltages of opposite polarity than those described above can be used, e.g., actuating a pixel can involve setting the appropriate column to $+V_{bias}$, and the appropriate row to -ΔV. In this embodiment, releasing the pixel is accomplished by setting the appropriate column to $-V_{bias}$, and the appropriate row to the same -ΔV, producing a zero volt potential difference across the pixel.

[0026] Figure 5B is a timing diagram showing a series of row and column signals applied to the 3x3 array of Figure 2 which will result in the display arrangement illustrated in Figure 5A, where actuated pixels are non-reflective. Prior to writing the frame illustrated in Figure 5A, the pixels can be in any state, and in this example, all the rows are at 0 volts, and all the columns are at +5 volts. With these applied voltages, all pixels are stable in their existing actuated or released states.

[0027] In the Figure 5A frame, pixels (1,1), (1,2), (2,2), (3,2) and (3,3) are actuated. To accomplish this, during a "line time" for row 1, columns 1 and 2 are set to-5 volts, and column 3 is set to +5 volts. This does not change the state of any pixels, because all the pixels remain in the 3-7 volt stability window. Row 1 is then strobed with a pulse that goes from 0, up to 5 volts, and back to zero. This actuates the (1,1) and (1,2) pixels and releases the (1,3) pixel. No other pixels in the array are affected. To set row 2 as desired, column 2 is set to -5 volts, and columns 1 and 3 are set to +5 volts. The same strobe applied to row 2 will then actuate pixel (2,2) and release pixels (2,1) and (2,3). Again, no other pixels of the array are affected. Row 3 is similarly set by setting columns 2 and 3 to -5 volts, and column 1 to +5 volts. The row 3 strobe sets the row 3 pixels as shown in Figure 5A. After writing the frame, the row potentials are zero, and the column potentials can remain at either +5 or -5 volts, and the display is then stable in the arrangement of Figure 5A. It will be appreciated that the same procedure can be employed for arrays of dozens or hundreds of rows and columns. It will also be appreciated that the timing, sequence, and levels of voltages used to perform row and column actuation can be varied widely within the general principles outlined above, and the above example is exemplary only, and any actuation voltage method can be used with the present invention.

[0028] The details of the structure of interferometric modulators that operate in accordance with the principles set forth above may vary widely. For example, Figures 6A-6C illustrate three different embodiments of the moving mirror structure. Each of the embodiments depicted in Figures 6A-6C comprise a moveable highly reflective element 14, a transparent substrate 20, and a thin film stack 31 layered upon said substrate 20, wherein said thin film stack 31 comprises a fixed partially reflective layer 16. Figure 6A is a cross section of the embodiment of Figure 1, where the moveable reflective layer 14 comprises a strip of metal material that is deposited on orthogonally extending supports 18. In Figure 6B, the moveable reflective material 14 is attached to supports at the corners only, on tethers 32. In Figure 6C, the moveable reflective material 14 is suspended from a deformable layer 34. This embodiment has benefits because the structural design and materials used for the reflective material 14 can be optimized with respect to the optical properties, and the structural design and materials used for the deformable layer 34 can be optimized with respect to desired mechanical properties. The production of various types of interferometric devices is described in a variety of published documents, including, for example, U.S. Published Application 2004/0051929. A wide variety of well known techniques may be used to produce the above described structures involving a series of material deposition, patterning, and etching steps.

[0029] Figures 7A-7C are schematic views of a basic package structure for an interferometric modulator. As shown in Figure 7A, the basic package structure 40 includes a transparent substrate 41 (e.g., glass) and a backplate or "cap" 42. As illustrated in Figures 7A-7C, an interferometric light modulator array 43 is encapsulated within the package structure 40. The backplate 42 may be formed of any suitable material, such as glass, metal, foil, polymer, plastic, ceramic, or semiconductor materials (*e.g.*, silicon).

[0030] A seal 44 is typically provided to join the transparent substrate 41 and backplate 42 to form the package structure 40. Depending on embodiments, the seal 44 may be a non-hermetic, semi-hermetic, or hermetic seal. An example of a hermetic sealing process is disclosed in U.S. Patent No. 6,589,625, the entirety of which is hereby incorporated by reference.

[0031] In one embodiment, a desiccant 46 is provided within the package structure 40 to reduce moisture within the package structure 40. In one embodiment, the desiccant 46 is positioned between the array 43 and the backplate 42. Desiccants may be used for packages that have either hermetic or semi-hermetic seals. Suitable desiccant materials include, but are not limited to, zeolites, molecular sieves, surface adsorbents, bulk adsorbents, and chemical reactants. The desiccant 46 can also be referred to as a getter material or can be used in addition to a getter material where the getter material is removing other materials as Oxygen or particles. In one embodiment, the amount of a desiccant used in the interior of the package 40 is chosen to absorb the water vapor that permeates through the seal 44 during the lifetime of the device 40.

[0032] Generally, the packaging process may be accomplished in a vacuum, pressure between a vacuum up to and including ambient pressure, or pressure higher than ambient pressure. The packaging process may also be accomplished in an environment of varied and controlled high or low pressure during the sealing process.

[0033] Figure 7B illustrates flux of water vapor into the package 40 and absorption of the permeated water vapor by the desiccant 46. Referring to Figure 7B, the desiccant 46 absorbs water or water vapor existing in the interior of the package 40. The desiccant 46 also absorbs water or water vapor 47 which has been permeated into the interior of the package 40 as shown in Figure 7B.

[0034] In one embodiment, the package structure 50 may eliminate the need for a desiccant as shown in Figure 7C. In this embodiment, the seal 44 is preferably a hermetic seal so that moisture traveling from the atmosphere into the interior of the package 50 is prevented or minimized. In another embodiment, instead of sealing the backplate 42 to the transparent substrate 41, a thin film (not shown) can be deposited on the transparent substrate 41 to encapsulate the array 43 within the package structure 50.

[0035] Figure 8 is a detailed side view of interferometric light modulating device 80 comprising a light modulating cavity 108 where optical resonance occurs between a fixed partially reflective layer 102 and a moveable highly reflective layer 106. A partially reflective layer 102 is a transmissive element that transmits light and may be partially reflective. A moveable highly reflective layer 106 is a reflective element that reflects light and may be partially transmissive. The partially reflective layer 102 is layered upon a transparent substrate 100, which may be any transparent substrate capable of having thin film, MEMS devices built upon it. Such transparent substances include, but are not limited to, glass, plastic, and transparent polymers. The partially reflective layer 102, depicted here as a thin film stack of multiple sublayers, typically comprises an electrode sublayer 110 and a primary mirror sublayer 120. The primary mirror sublayer 120 may be made of a metallic film. In this embodiment an insulatingsublayer 130 is disposed above the primary mirror sublayer 120 and functions as an insulator and also enhances reflection from the partially reflective layer 102. The moveable highly reflective layer 106, depicted here as a membrane of multiple sublayers, typically includes a secondary mirror sublayer 140 and an electrode sublayer 150. The secondary mirror sublayer 140 may be made of a metallic film. Posts 104 are formed to support the moveable highly reflective layer 106. In one embodiment, the posts 104 are insulators. The electrode layers 110 and 150 are connected to the voltage source (V) shown in Figure 1 so that the voltage (V) can be applied across the two layers 102 and 106. Other interferometric modulator configurations and operating modes are disclosed in U.S. Patent No. 5,835,255, which is hereby incorporated by reference in its entirety.

[0036] As used herein, the terms reflective element and transmissive element are to be given their broadest ordinary meaning. A reflective element is at least one layer that reflects light and may be partially transmissive to light. The term reflective element may refer to, but is not limited by, the elements described herein as the moveable highly reflective layer 106 or the secondary mirror sublayer 140. A transmissive element is at least one layer that transmits light and may partially reflect light. The term transmissive element may refer to, but is not limited by, the elements described herein as the fixed partially reflective layer 102 or the primary mirror sublayer 120.

[0037] Referring to Figure 8, in the driven state of an interferometric light modulating device 80, the moveable highly reflective layer 106, depicted here as a membrane, may make contact with the fixed partially reflective layer 102, depicted here as a thin film stack. When a potential difference is applied to layers 102 and 106, a capacitor is formed between these two layers, which creates electrostatic forces that pull the highly reflective layer 106 towards the partially reflective layer 102. This results in the cavity 108 collapsing. If the voltage is high enough, the highly reflective layer 106 may be deformed and forced against the partially reflective layer 102 completely collapsing the cavity 108. When no potential difference is applied, however, the mechanical restoration forces of the moveable highly reflective layer 106 and its surrounding structure may return layer 106 to its original position, thereby restoring the cavity 108. But even in the undriven state, both of the layers 106 and 102 are closely located to each other, e.g., about 0.2 μm. Thus, the mechanical restoration forces of the moveable highly reflective layer 106 should be carefully balanced with the electrostatic forces created between the layer 106 and the fixed partially reflective layer 102 in order to ensure proper operation and responsiveness of the interferometric light modulating device 80.

[0038] There are additional attractive forces that may disturb the balance of forces described above. These additional attractive or adhesive forces include "capillary water condensation" and/or "van der Waals forces." During the lifetime of an interferometric light modulating device, water vapor (or water) can continuously permeate into the interior of the device (as depicted in Figure 7B) and the permeated water vapor can exist on the surfaces of each of the layers 102 and 106. The water vapor can cause the two layers 102 and 106 to have an additional attractive capillary force between them due to water condensation. Furthermore, the "van der Waals" forces, which are short range forces causing adjacent materials to become attracted at the molecular level, can cause the layers 102 and 106 to have an additional attractive force between them. In an interferometric light modulating device 80, the moveable highly reflective layer 106, including the secondary mirror sublayer 140, moves toward and from the fixed partially reflective layer 102, which includes the primary mirror sublayer 120, depending on the operation state. If there are additional attractive forces between layers 102 and 106, the device 80 may fail to operate properly, even to the point to where the layers may stick together. Thus, in embodiments of the invention, means for reducing attractive forces between layers 102 and 106 include an anti-stiction coating applied on one or more of the layer surfaces (or sublayer surfaces) of an interferometric light modulating device 80 so that the additional attractive forces between adjacent surfaces due to events such as capillary water condensation or van der Waals forces may be minimized or eliminated.

[0039] As used herein, the term anti-stiction coating is to be given its broadest ordinary meaning, including but not limited to a material that reduces attractive forces between surfaces. The term anti-stiction coating may refer to, but is not limited to, a self-aligned monolayer (also referred to as a self-assembled monolayer). In some embodiments, an example of an anti-stiction coating includes, but is not limited to, a self-aligning monolayer such as one or more of the following: fluoro silane, chloro-fluoro silane, methoxy silane, trichlorosilane, perfluorodecanoic carboxylic acid, octadecyltrichlorosilane (OTS), or dichlorodimethylsilane. In some embodiments, an example of an anti-stiction coating includes, but is not limited to, polymeric materials such as one or more of the following: teflon, silicone, polystyrene, polyurethane (both standard and ultraviolet curable), a block copolymer containing a hydrophobic component (for example poly-methylmethacrylate), or polysilazane (especially with polisiloxane). In some embodiments, an example of an anti-stiction coating includes, but is not limited to, inorganic materials such as one or more of the following: graphite, diamond-like carbon (DLC), silicon carbide (SiC), a hydrogenated diamond coating, or fluorinated DLC. In some embodiments, the anti-stiction coating does not significantly adversely affect the optical responses or characteristics of the optical cavity 108, such as the optical responses and/or characteristics of layers 102 or 106.

[0040] Figure 9 illustrates an interferometric light modulating device 80 with portions of layers 102 and 106 within the light modulating cavity 108 coated with anti-stiction material 160 and 170, respectively, according to one embodiment of the invention. In other embodiments, at least a portion of all surfaces within the light modulating cavity 108 are coated with an anti-stiction material, including the posts 104.

[0041] Figure 10 illustrates an alternative embodiment of interferometric light modulating device 80 with layers 102 and 106 coated with anti-stiction material according to another embodiment of the invention. In this embodiment, anti-stiction coating layers 160 and 170 are formed on surfaces of the layers 106 and 102 that are interior to the cavity 108. In this embodiment, the moveable highly reflective layer 106 includes its own vertical support mechanism via a domed shape, unlike the Figure 9 embodiment where there are separate posts 104 formed between the two layers 106 and 102. Although Figures 9 and 10 depict anti-stiction coating layers 160 and 170 as covering the entire surface of layers 102 and 106 within light modulating cavity 108, only coating a portion of layer 102 and/or layer 106 is contemplated by the present invention. For example, in one embodiment, only a portion of layer 102 comprises an anti-stiction coating. In another embodiment, only a portion of layer 106 comprises an anti-stiction coating.

[0042] Figures 11A, 11B, and 11C illustrate an interferometric light modulating device 80 with selective coating of one or more layers according to embodiments of the invention. In Figure 11 A, the anti-stiction layer 160 is provided on the surface of the moveable highly reflective layer 106 and not on the fixed partially reflective layer 102. Conversely, in Figure 11B, the anti-stiction layer 170 is provided on the surface of layer 102 and not on layer 106.

[0043] As depicted in Figure 11C, one way to accomplish the selective coating illustrated in Figures 11A and 11C is to use a covering element 175. During the coating process, the surfaces which are not intended to be coated, depicted here as the fixed partially reflective layer 102, may be covered with the covering element 175, such as a sacrificial material, so that the anti-stiction coating layer is not formed on the surfaces covered by the covering element 175. In other embodiments, the covering element 175 may be provided on any surface(s) within the cavity 108 where an anti-stiction coating is not desired, such as the surface of posts 104 that are within the cavity 108.

[0044] Figures 12A and 12B illustrate an interferometric light modulating device package 85 with layers 102 and layer 106 coated with anti-stiction material according to another embodiment of the invention. In these embodiments, layers 102 and 106 are encapsulated within the package 85 and the application of the anti-stiction coating is performed after the package 85 is fabricated. In one embodiment, the backplate 42 is a recessed structure or a formed structure, but not necessarily so if the amount of a desiccant (not shown in Figures 12A and 12B) in the package 85 is reduced or removed. In this embodiment, the requirements on the recessed depth can be lessened or eliminated. In one embodiment, the use of anti-stiction layers 160 and 170 (e.g., self-aligning monolayers) can allow for altered cap (backplate) designs to reduce the required recess compared to the recess needed if using a desiccant.

[0045] In the embodiments depicted in Figures 12A and 12B, an orifice 176 is defined in the package, e.g., in the seal 44 as shown in Figure 12A or 12B. In these embodiments, the anti-stiction coating material may be supplied into the interior of the package 85 via the orifice 176. In another embodiment, two orifices 176 and 177 are created in the package 85, e.g., in the seals 44 and 45 for the delivery of the anti-stiction material, as shown in Figure 12B. In still another embodiment, more than two orifices (not shown) can be defined in the package 85 and the anti-stiction coating material is supplied into the interior of the package 20 via the orifices. In other embodiments, orifice(s) may be formed in the substrate 100 or the backplate 42. Thus, having orifice(s) within the seal 44, substrate 100, and/or backplate 42 for the delivery of the anti-stiction coating is within the scope of the present invention.

[0046] In these embodiments, the orifice(s) formed in the package 85 may also be used to remove water vapor from the interior of the package 85. After the orifice(s) are no longer needed, they may be plugged, welded or sealed, depending on the nature of the orifice(s).

[0047] Figure 13 illustrates an anti-stiction layer coating system for an interferometric light modulating device 80 according to one embodiment of the invention. Referring to Figure 13, the system 180 comprises a chamber 181, a coating material container 182, a valve 184, and a carrier gas reservoir 186. A person skilled in the art will appreciate that the system 180 is only exemplary and other coating systems, which can exclude some of the elements of the system 180 and/or include additional elements, may be used. In one embodiment, the system 180 may perform an anti-stiction coating for the fabricated package as shown in Figures 11A, 11B and 11C.

[0048] The valve 184 controls feeding the coating material into the chamber 181. In one embodiment, the valve 184 is controlled by a computing device. In one embodiment, the valve 184 may be any suitable valve for this anti-stiction coating process. In another embodiment, the valve 184 may be used to properly mix and time the carrier gas with the XeF_2 etchant gas.

[0049] The container 182 contains anti-stiction coating material. In various embodiments, as discussed above, an example of an anti-stiction coating can include, but is not limited to, the following: a self-aligning (or self-assembling) monolayer such as OTS, dichlorodimethylsilane, etc.; other polymeric materials such as teflon, polystyrene, etc.; or other inorganic materials such as graphite, DLC, etc. In another embodiment, the coating material includes any anti-stiction material which does not significantly adversely affect the optical responses or characteristics of the optical cavity 108, such as the optical responses and/or characteristics of layers 102 or 106.

[0050] In one embodiment, the carrier gas reservoir 186 contains a carrier gas such as nitrogen (N_2) or argon, which is used to transport the anti-stiction coating material to the chamber 181 by a known pumping mechanism. In another embodiment, the carrier gas can incorporate other types of getter material or chemistries as long as the performance of the interferometric light modulating device 80 is not significantly adversely affected. In another embodiment, the carrier gas can be integrated into the chemistry of the release etchant gas of XeF_2.

[0051] Figure 14 is an exemplary flowchart describing an anti-stiction coating process according to one embodiment of the invention. A skilled person will appreciate that depending on the embodiments, additional states may be added, others removed, or the order of the states changes. Referring to Figures 7-12, the anti-stiction coating procedure according to embodiments of invention will be described in more detail.

[0052] Anti-stiction coating material is provided in step 90. The interferometric light modulating device 80, whose surface(s), such as layers 102 and/or 106, will be coated, is placed in the chamber 181 at step 92. An anti-stiction layer coating is applied on the surfaces to be coated in step 94. In one embodiment, the surface of layers 102 and/or 106, such as a mirror surface or an insulator surface, may be heated so that water vapor existing on the surfaces to be coated is removed before the anti-stiction coating is performed. In one embodiment, the insulating sublayer 130 is not provided and the anti-stiction layer is formed on the surface of the primary mirror sublayer 120 (depicted in Figure 8). In another embodiment, the anti-stiction layer is formed on the surface of the secondary mirror sublayer 140 (depicted in Figure 8). In another embodiment, the anti-stiction layer is formed on the surfaces of the insulatingsublayer 130 and secondary mirror sublayer 140 (depicted in Figure 8).

[0053] In one embodiment of the anti-stiction coating process, the anti-stiction layer is formed during an interferometric light modulating device fabrication process. For example, the anti-stiction layer coating may be incorporated into a "release" process. In the release process, a sacrificial layer 175 (depicted in Figure 11C) of the interferometric light modulating device 80 is etched away with the use of a gas, for example, XeF_2. In one embodiment, a mixture of the anti-stiction coating material and XeF_2 may be pumped into the chamber 181. In another embodiment, the anti-stiction coating can be applied after the XeF_2 etching is complete. Typically, the release process is performed by a MEMS etching system, for example, X3 Series Xetch available from XACIX, USA, and MEMS ETCHER available from Penta Vacuum, Singapore.

[0054] In another embodiment of the anti-stiction coating process, the anti-stiction layer is formed uniformly in its thickness. In another embodiment, the thickness of the anti-stiction coating layer may not be uniform. Generally, an anti-stiction layer such as a self-aligned monolayer is a thin film coating and thus it does not significantly affect the optical characteristics (or responses) of the layers 102 or 106, including mirrors 120 and 140 (depicted in Figure 8), even if the anti-stiction coating is not uniform.

[0055] In one embodiment, the anti-stiction coating is performed using a process disclosed in, for example, "Dichlorodimethylsilane as an Anti-Stiction Monolayer for MEMS," Journal of Microelectromechanical Systems, Vol. 10, No. 1, March 2001 and U.S. Patent No. 6,335,224, which are hereby incorporated by reference. In another embodiment, the anti-stiction coating is performed using a deposition process, such as chemical vapor deposition or a physical vapor deposition. In still another embodiment, any suitable anti-stiction coating method on mirror or insulator surfaces, either known or developed in the future, can be used. The anti-stiction coating process is then completed in step 96 and the interferometric light modulating device 80 is removed from the chamber 181 in step 98.

[0056] Figure 15 is a flowchart describing an anti-stiction coating method for an interferometric light modulating device according to one embodiment of the invention. This Figure illustrates another method for reducing attractive forces between layers within a light modulating device. In accordance with this method, the interferometric light modulating devices described in instant application may be fabricated, including the devices described with reference toFigures 7-12. In this method, a transmissive element is provided in step 200. The transmissive element may be provided by layering the transmissive element upon a substrate. This transmissive element may be, for example, the fixed partially reflective layer 102 or any of its sublayers, such as the primary mirror sublayer 120, the insulating sublayer 130, or electrode sublayer 110 depicted in Figure 8. A reflective element is provided in step 210. The reflective element may be provided by forming a stack over the transmissive element. This reflective element may be, for example, the moveable highly reflective layer 106 or any of its sublayers, such as the secondary mirror sublayer 140 or the electrode sublayer 150 depicted in Figure 8. An anti-stiction coating is then provided in step 220, wherein the anti-stiction coating is located between at least a portion of the reflective element and the transmissive element. The anti-stiction coating may be provided as described herein with reference to Figures 11-14. A person skilled in the art will appreciate that the method depicted in Figure 15 is only exemplary and other coating methods, which may exclude some of the elements or steps in the depicted method and/or include additional elements or steps, may be used.

[0057] For example, in another embodiment, the reflective element may be provided before the transmissive element is provided. Also, in other embodiments, the anti-stiction coating is provided after either the reflective element or the transmissive element is provided. Also, in other embodiments, covering elements, such as a sacrificial layer, may be applied to portions of the interferometric light modulating device where an anti-stiction coating is not desired. Then, if desired, after the anti-stiction coating is provided, other elements may make contact with the coated covering element(s), thereby providing an anti-stiction coating by transfer contact. The covering elements and/or sacrificial layers may then be etched. In other embodiments, a sacrificial layer is provided between the reflective element and the transmissive element and the sacrificial layer is then etched prior to providing the anti-stiction coating. In other embodiments, the transmissive element and reflective element are packaged into an interferometric light modulating device package, such as one depicted in Figures 12A and 12B, prior to providing the anti-stiction coating. In other embodiments the anti-stiction coating is provided prior to the packaging.

[0058] Figures 16A and 16B are system block diagrams illustrating an embodiment of a display device 2040. The display device 2040 can be, for example, a cellular or mobile telephone. However, the same components of display device 2040 or slight variations thereof are also illustrative of various types of display devices such as televisions and portable media players.

[0059] The display device 2040 includes a housing 2041, a display 2030, an antenna 2043, a speaker 2045, an input device 2048, and a microphone 2046. The housing 2041 is generally formed from any of a variety of manufacturing processes as are well known to those of skill in the art, including injection molding, and vacuum forming. In addition, the housing 2041 may be made from any of a variety of materials, including but not limited to plastic, metal, glass, rubber, and ceramic, or a combination thereof. In one embodiment the housing 2041 includes removable portions (not shown) that may be interchanged with other removable portions of different color, or containing different logos, pictures, or symbols.

[0060] The display 2030 of exemplary display device 2040 may be any of a variety of displays, including a bi-stable display, as described herein. In other embodiments, the display 2030 includes a flat-panel display, such as plasma, EL, OLED, STN LCD, or TFT LCD as described above, or a non-flat-panel display, such as a CRT or other tube device, as is well known to those of skill in the art. However, for purposes of describing the present embodiment, the display 2030 includes an interferometric modulator display, as described herein.

[0061] The components of one embodiment of exemplary display device 2040 are schematically illustrated in Figure 16B. The illustrated exemplary display device 2040 includes a housing 2041 and can include additional components at least partially enclosed therein. For example, in one embodiment, the exemplary display device 2040 includes a network interface 2027 that includes an antenna 2043 which is coupled to a transceiver 2047. The transceiver 2047 is connected to the processor 2021, which is connected to conditioning hardware 2052. The conditioning hardware 2052 may be configured to condition a signal (e.g. filter a signal). The conditioning hardware 2052 is connected to a speaker 2045 and a microphone 2046. The processor 2021 is also connected to an input device 2048 and a driver controller 2029. The driver controller 2029 is coupled to a frame buffer 2028 and to the array driver 2022, which in turn is coupled to a display array 2030. A power supply 2050 provides power to all components as required by the particular exemplary display device 2040 design.

[0062] The network interface 2027 includes the antenna 2043 and the transceiver 2047 so that the exemplary display device 2040 can communicate with one or more devices over a network. In one embodiment the network interface 2027 may also have some processing capabilities to relieve requirements of the processor 2021. The antenna 2043 is any antenna known to those of skill in the art for transmitting and receiving signals. In one embodiment, the antenna transmits and receives RF signals according to the IEEE 802.11 standard, including IEEE 802.11(a), (b), or (g). In another embodiment, the antenna transmits and receives RF signals according to the BLUETOOTH standard. In the case of a cellular telephone, the antenna is designed to receive CDMA, GSM, AMPS or other known signals that are used to communicate within a wireless cell phone network. The transceiver 2047 pre-processes the signals received from the antenna 2043 so that they may be received by and further manipulated by the processor 2021. The transceiver 2047 also processes signals received from the processor 2021 so that they may be transmitted from the exemplary display device 2040 via the antenna 2043.

[0063] In an alternative embodiment, the transceiver 2047 can be replaced by a receiver. In yet another alternative embodiment, network interface 2027 can be replaced by an image source, which can store or generate image data to be sent to the processor 2021. For example, the image source can be a digital video disc (DVD) or a hard-disc drive that contains image data, or a software module that generates image data.

[0064] Processor 2021 generally controls the overall operation of the exemplary display device 2040. The processor 2021 receives data, such as compressed image data from the network interface 2027 or an image source, and processes the data into raw image data or into a format that is readily processed into raw image data. The processor 2021 then sends the processed data to the driver controller 2029 or to frame buffer 2028 for storage. Raw data typically refers to the information that identifies the image characteristics at each location within an image. For example, such image characteristics can include color, saturation, and gray-scale level.

[0065] In one embodiment, the processor 2021 includes a microcontroller, CPU, or logic unit to control operation of the exemplary display device 2040. Conditioning hardware 2052 generally includes amplifiers and filters for transmitting signals to the speaker 2045, and for receiving signals from the microphone 2046. Conditioning hardware 2052 may be discrete components within the exemplary display device 2040, or may be incorporated within the processor 2021 or other components.

[0066] The driver controller 2029 takes the raw image data generated by the processor 2021 either directly from the processor 2021 or from the frame buffer 2028 and reformats the raw image data appropriately for high speed transmission to the array driver 2022. Specifically, the driver controller 2029 reformats the raw image data into a data flow having a raster-like format, such that it has a time order suitable for scanning across the display array 2030. Then the driver controller 2029 sends the formatted information to the array driver 2022. Although a driver controller 2029, such as a LCD controller, is often associated with the system processor 2021 as a stand-alone Integrated Circuit (IC), such controllers may be implemented in many ways. They may be embedded in the processor 2021 as hardware, embedded in the processor 2021 as software, or fully integrated in hardware with the array driver 2022.

[0067] Typically, the array driver 2022 receives the formatted information from the driver controller 2029 and reformats the video data into a parallel set of waveforms that are applied many times per second to the hundreds and sometimes thousands of leads coming from the display's x-y matrix of pixels.

[0068] In one embodiment, the driver controller 2029, array driver 2022, and display array 2030 are appropriate for any of the types of displays described herein. For example, in one embodiment, driver controller 2029 is a conventional display controller or a bi-stable display controller (e.g., an interferometric modulator controller). In another embodiment, array driver 2022 is a conventional driver or a bi-stable display driver (e.g., an interferometric modulator display). In one embodiment, a driver controller 2029 is integrated with the array driver 2022. Such an embodiment is common in highly integrated systems such as cellular phones, watches, and other small area displays. In yet another embodiment, display array 2030 is a typical display array or a bi-stable display array (e.g., a display including an array of interferometric modulators).

[0069] The input device 2048 allows a user to control the operation of the exemplary display device 2040. In one embodiment, input device 2048 includes a keypad, such as a QWERTY keyboard or a telephone keypad, a button, a switch, a touch-sensitive screen, a pressure- or heat-sensitive membrane. In one embodiment, the microphone 2046 is an input device for the exemplary display device 2040. When the microphone 2046 is used to input data to the device, voice commands may be provided by a user for controlling operations of the exemplary display device 2040.

[0070] Power supply 2050 can include a variety of energy storage devices as are well known in the art. For example, in one embodiment, power supply 2050 is a rechargeable battery, such as a nickel-cadmium battery or a lithium ion battery. In another embodiment, power supply 2050 is a renewable energy source, a capacitor, or a solar cell, including a plastic solar cell, and solar-cell paint. In another embodiment, power supply 2050 is configured to receive power from a wall outlet.

[0071] In some implementations control programmability resides, as described above, in a driver controller which can be located in several places in the electronic display system. In some cases control programmability resides in the array driver 2022. Those of skill in the art will recognize that the above-described optimization may be implemented in any number of hardware and/or software components and in various configurations.

[0072] While the above detailed description has shown, described, and pointed out novel features of the invention as applied to various embodiments, it will be understood that various omissions, substitutions, and changes in the form and details of the device or process illustrated may be made by those skilled in the art without departing from the spirit of the invention. As will be recognized, the present invention may be embodied within a form that does not provide all of the features and benefits set forth herein, as some features may be used or practiced separately from others.

Claims

1. A method for manufacturing an interferometric light modulating device, comprising:

   providing a transmissive element;
   providing a reflective element; and
   providing an anti-stiction coating, wherein said anti-stiction coating is located between at least a portion of said reflective element and said transmissive element.

2. The method of claim 1, further comprising:

   providing a sacrificial layer located between said reflective element and said transmissive element; and
   etching at least a portion of the sacrificial material prior to providing an anti-stiction coating.

3. The method of claim 1, further comprising:

   providing a sacrificial layer located between said reflective element and said transmissive element, wherein said anti-stiction coating is provided on at least a portion of said sacrificial layer.

4. The method of claim 1, further comprising:

   providing a transparent substrate;
   providing a seal;
   providing a backplate; and
   adhering said substrate and said backplate with said seal, wherein said reflective element, said transmissive element, and said anti-stiction coating are located between said substrate and said backplate.

5. The method of claim 4, wherein said steps of providing a substrate, seal and a backplate, and adhering said substrate and said backplate with said seal occur prior to said step of providing an anti-stiction coating.

6. The method of claim 4, wherein said step of providing an anti-stiction coating occurs prior to said step of adhering said substrate and said backplate with said seal.

7. The method of claim 4, wherein said seal, said substrate or said backplate have at least one orifice for providing said anti-stiction coating.

8. The method of claim 4, further comprising providing a desiccant, wherein said desiccant is located between said substrate and said backplate.

9. The method of claim 1, wherein said anti-stiction

coating comprises a self-aligning monolayer.

10. The method of claim 1, wherein said anti-stiction coating comprises at least one of: teflon, perfluorodecanoic carboxylic acid, octadecyltrichlorosilane (OTS), dichlorodimethylsilane, fluoro silane, chloro-fluoro silane, methoxy silane, trichlorosilane, silicone, polystyrene, polyurethane, a block copolymer containing a hydrophobic component, polysilazane, graphite, diamond-like carbide (DLC), silicon carbide (SiC), hydrogenated diamond coating, and fluorinated DLC.

11. The method of claim 1, wherein said anti-stiction coating is provided on at least a portion of said reflective element.

12. The method of claim 1, wherein said anti-stiction coating is provided on at least a portion of said transmissive element.

13. An interferometric light modulating device made or manufacturable by the method of any one of claims 1 to 12.

14. An electronic microelectromechanical systems (MEMS) device, comprising:

reflective means for reflecting light;
transmissive means for transmitting light therethrough;
modulating means for modulating light transmitted through said transmissive means; and
means for reducing attractive forces between said reflective means and said transmissive means.

15. The device of claim 14, wherein said reflective means comprises a mirror.

16. The device of claim 14 or 15, wherein said transmissive means comprises a partially reflective mirror.

17. The device of claim 14, 15 or 16, wherein said modulating means comprises an array of interferometric modulators.

18. The device of claim 14, 15, 16 or 17, wherein said reducing means comprises an anti-stiction coating

19. The device of claim 18, wherein said anti-stiction coating is applied on at least a portion of said transmissive means.

20. The device of claim 18, wherein said anti-stiction coating is applied on at least a portion of said reflective means.

21. The device of claim 14, further comprising a transparent substrate, wherein said substrate is adhered to a backplate with a seal to form a sealed package, and wherein said reflective means and said transmissive means are located within said sealed package.

22. The device of claim 21, further comprising a desiccant, wherein said desiccant is located within said sealed package.

23. The device of claim 21, further comprising at least one orifice in said package.

24. The device of claim 23, wherein said at least one orifice is an orifice in said seal, said substrate or said backplate.

25. The device of claim 18, wherein said anti-stiction coating comprises a self-aligning monolayer.

26. The device of claim 18, wherein said anti-stiction coating comprises at least one of: teflon, perfluorodecanoic carboxylic acid, octadecyltrichlorosilane (OTS), dichlorodimethylsilane, fluoro silane, chloro-fluoro silane, methoxy silane, trichlorosilane, silicone, polystyrene, polyurethane, a block copolymer containing a hydrophobic component, polysilazane, graphite, diamond-like carbide (DLC), silicon carbide (SiC), hydrogenated diamond coating, and fluorinated DLC.

27. The device of claim 14, further comprising a sacrificial layer located between said reflective means and said transmissive means, wherein said means for reducing attractive forces comprises an anti-stiction coating applied to at least a portion of said sacrificial layer.

28. The device of claim 14, wherein said MEMS device comprises an interferometric modulator.

29. The device of claim 14, further comprising:

a processor that is in electrical communication with said modulating means, said processor being configured to process image data; and
a memory device in electrical communication with said processor.

30. The device of claim 29, further comprising a driver circuit configured to send at least one signal to said modulating means.

31. The device of claim 30, further comprising a controller configured to send at least a portion of said image data to said driver circuit.

32. The device of claim 29, further comprising an image source module configured to send said image data to said processor.

33. The device of claim 32, wherein said image source module comprises at least one of a receiver, transceiver, and transmitter.

34. The device of claim 29, further comprising an input device configured to receive input data and to communicate said input data to said processor.

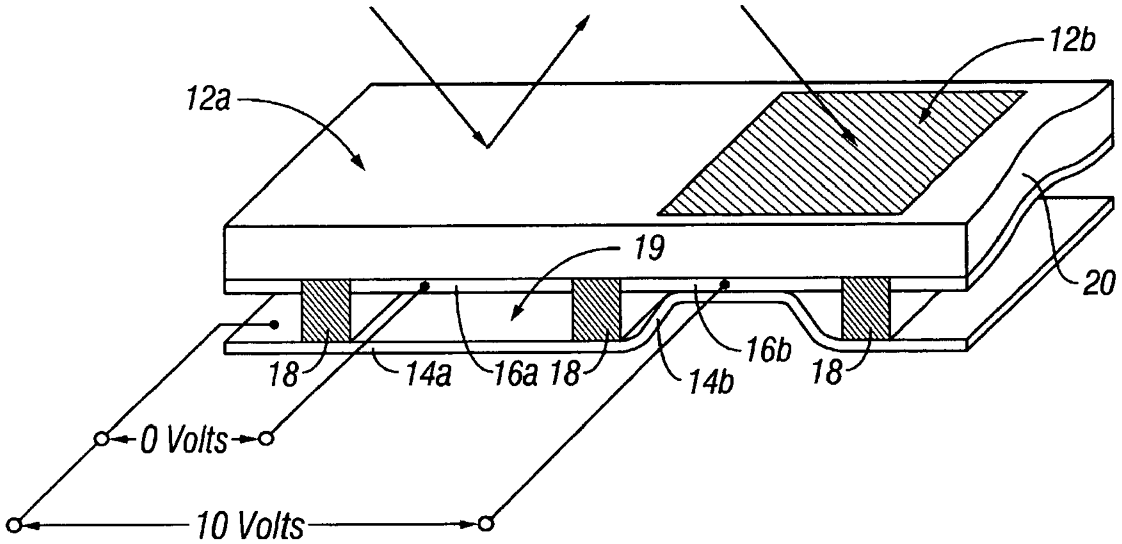

FIG. 1

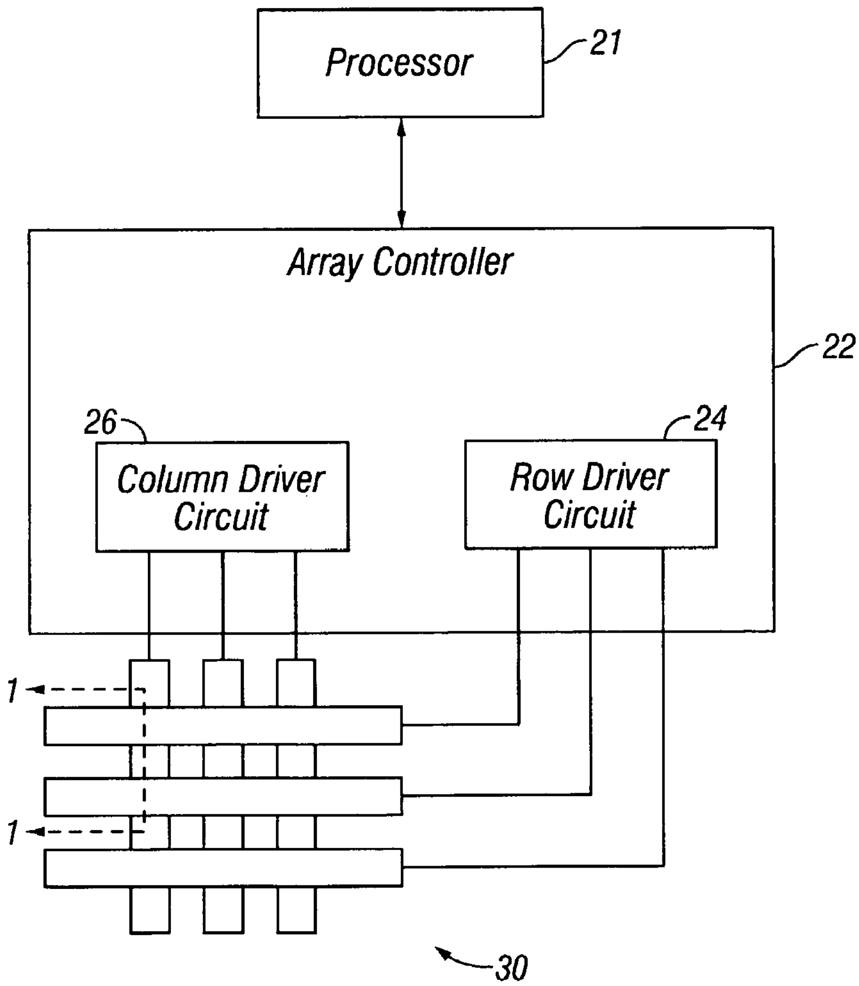
Processor
21
Array Controller
22
26
24
Column Driver Circuit
Row Driver Circuit
1
1
30

FIG. 2

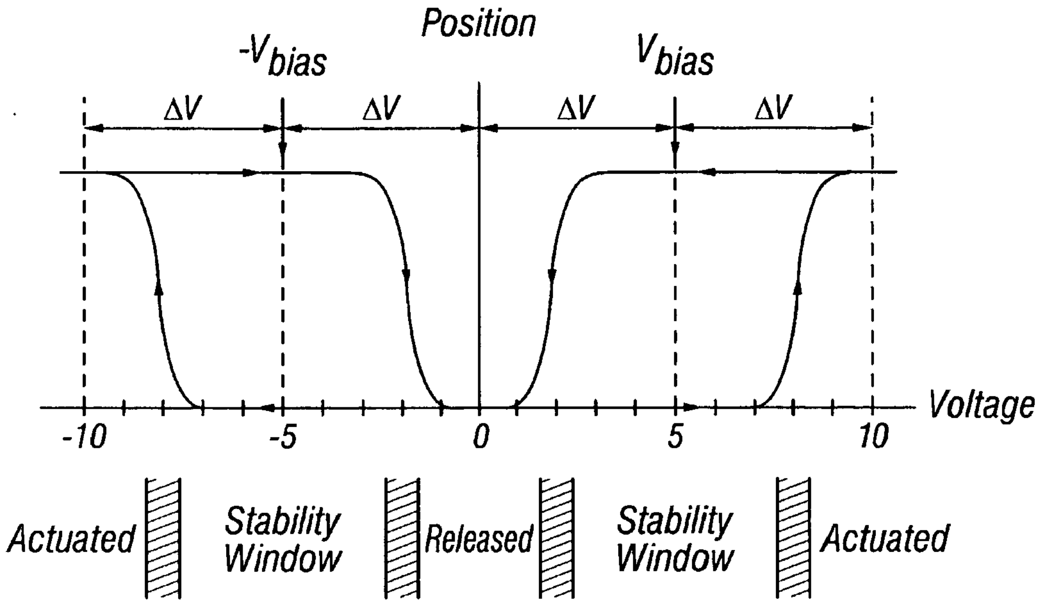

FIG. 3

Column Output Signals

Row Output Signals	$+V_{bias}$	$-V_{bias}$
0	Stable	Stable
$+\Delta V$	Release	Actuate
$-\Delta V$	Actuate	Release

FIG. 4

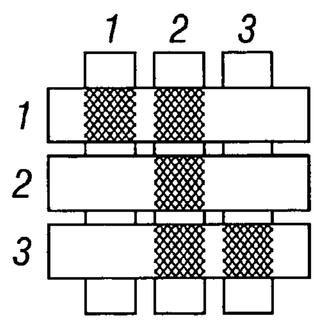
1
2
3
1
2
3

FIG. 5A

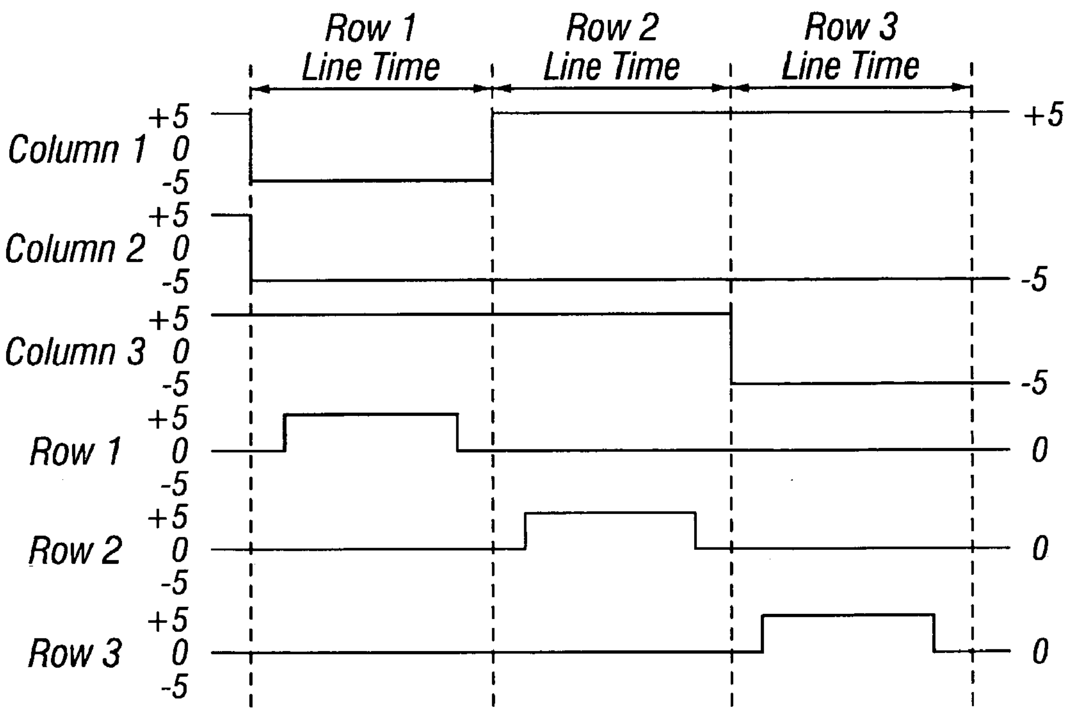
Row 1
Line Time
Row 2
Line Time
Row 3
Line Time
Column 1
Column 2
Column 3
Row 1
Row 2
Row 3
+5
0
-5

FIG. 5B

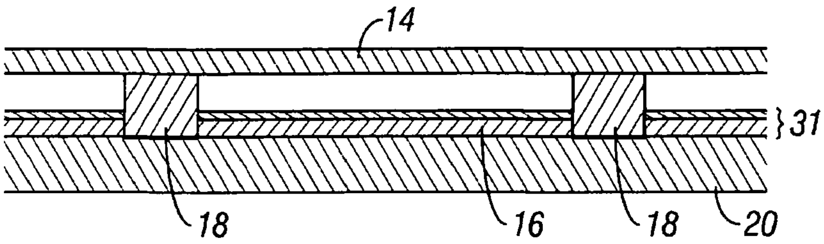

FIG. 6A

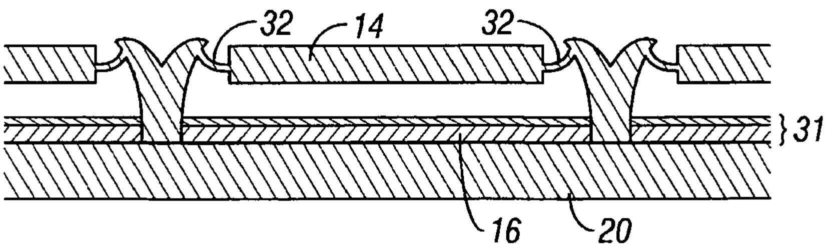

FIG. 6B

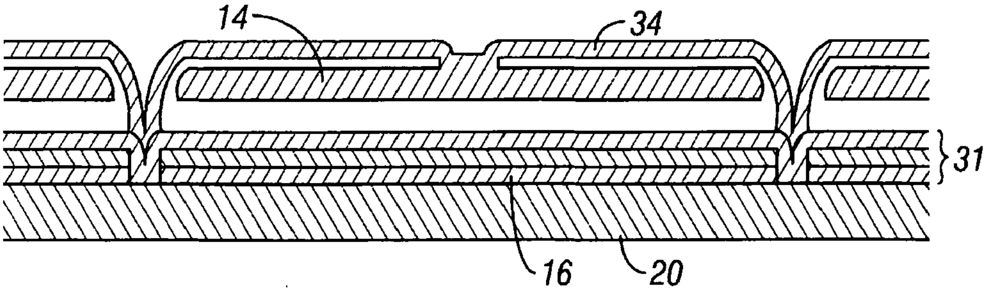

FIG. 6C

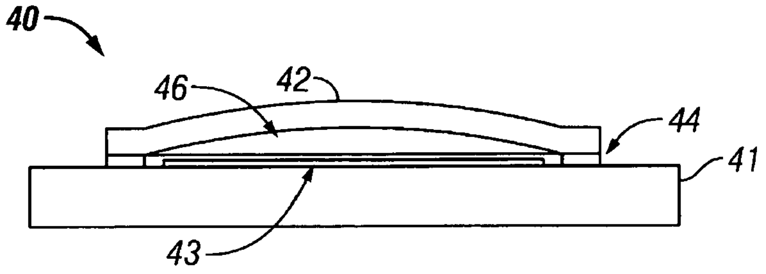

FIG. 7A

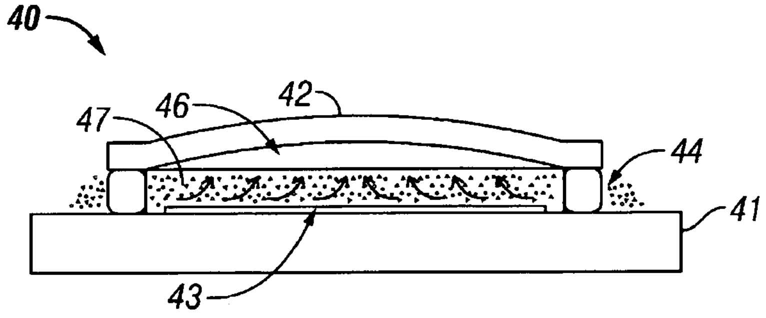

FIG. 7B

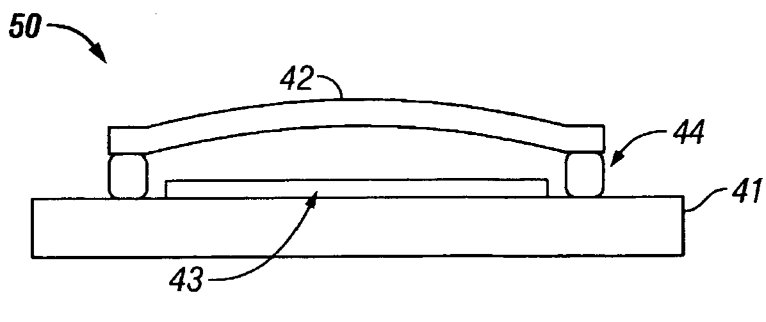

FIG. 7C

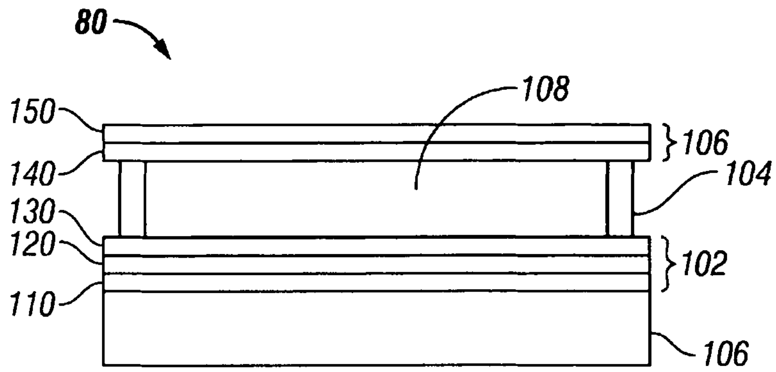

FIG. 8

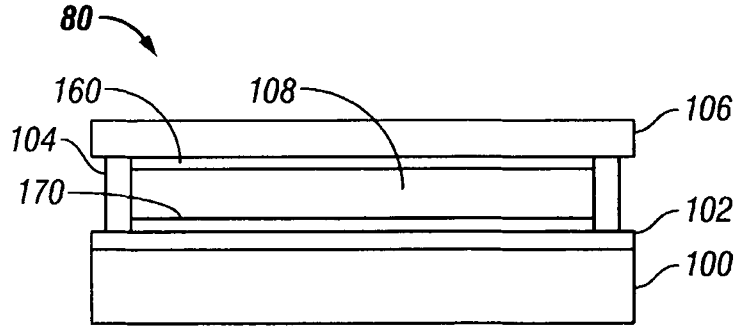

FIG. 9

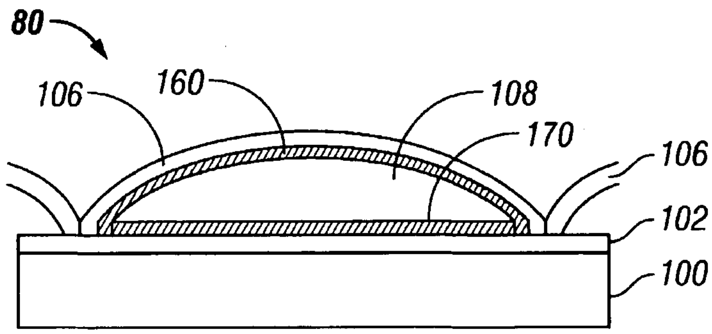

FIG. 10

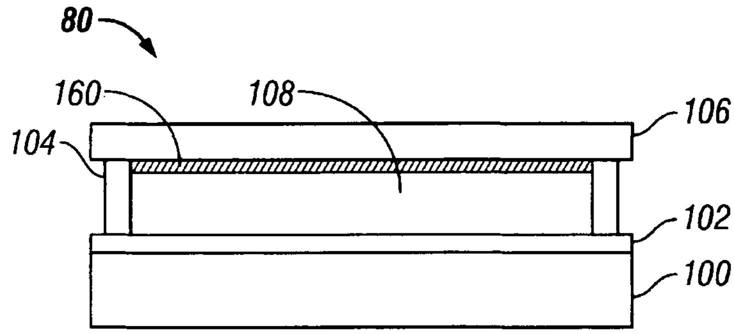

FIG. 11A

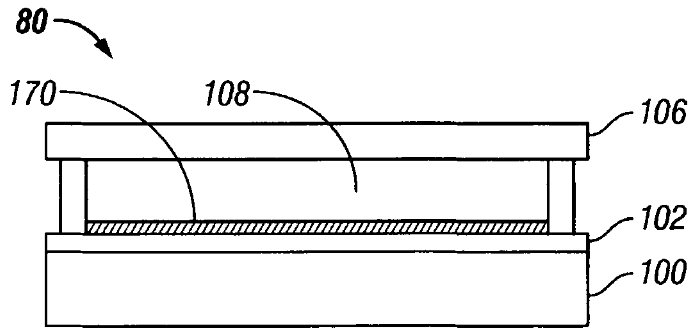

FIG. 11B

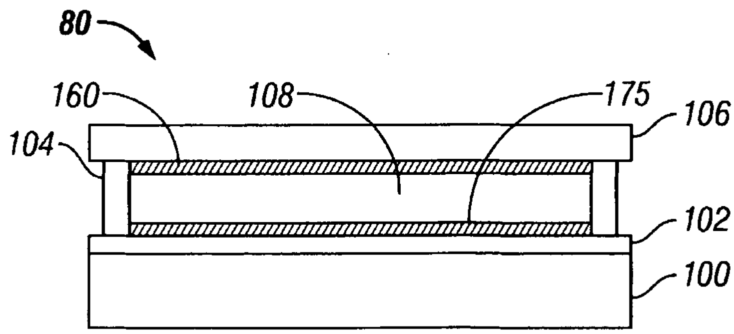

FIG. 11C

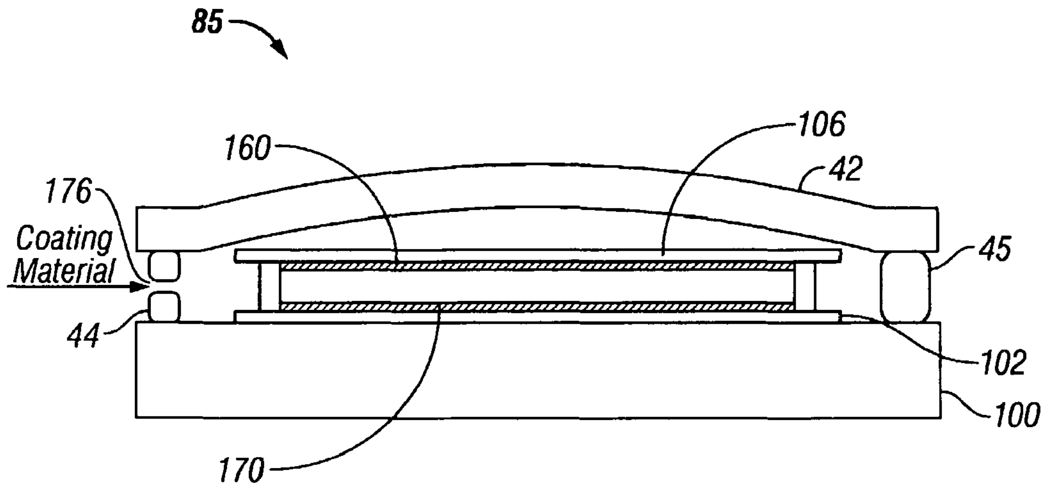

FIG. 12A

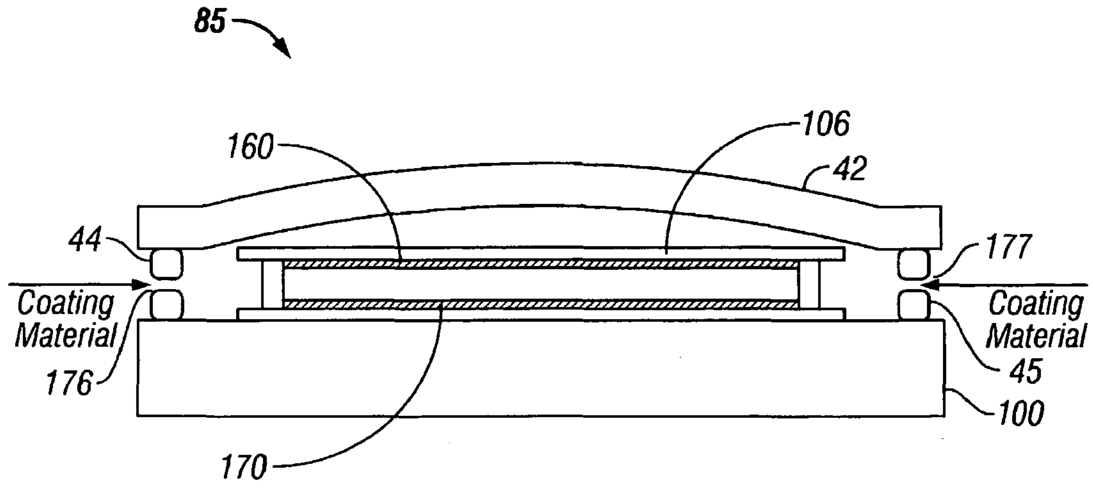

FIG. 12B

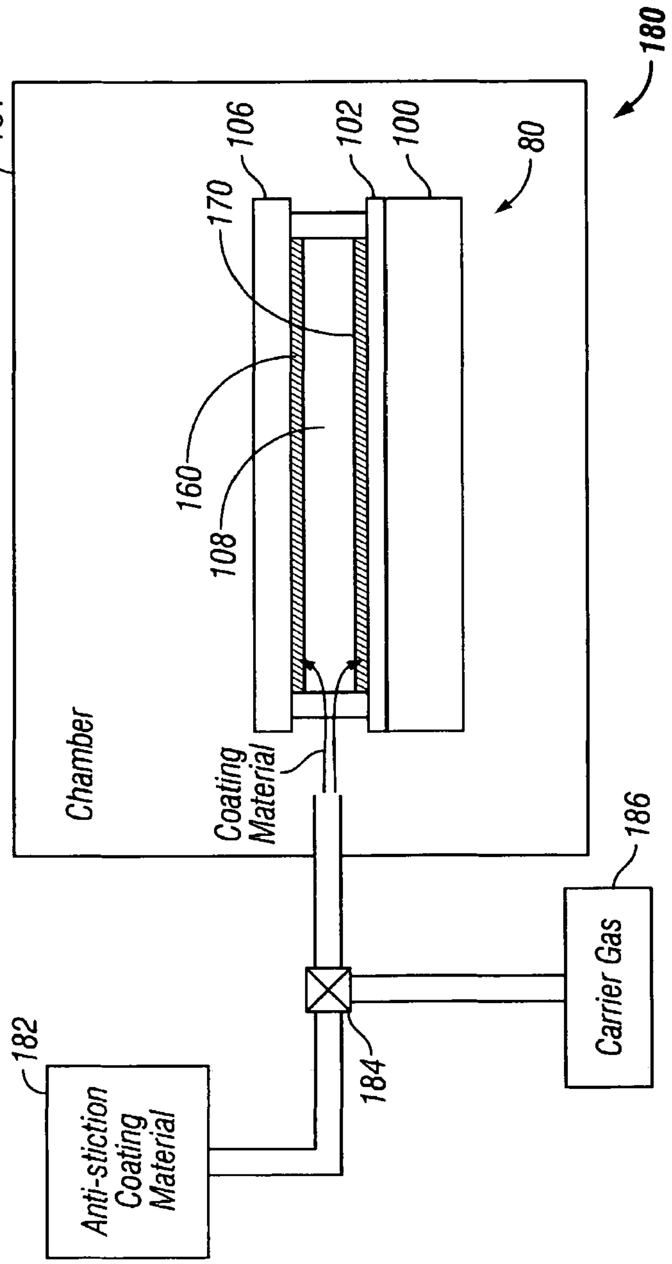
180
181
106
102
100
80
170
160
108
Chamber
Coating Material
182
Anti-stiction Coating Material
184
186
Carrier Gas

FIG. 13

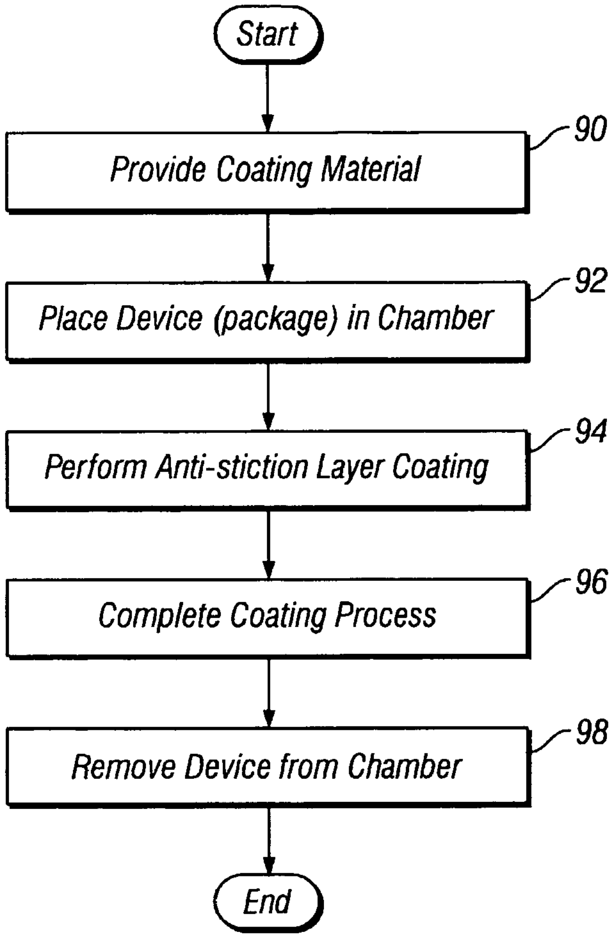
Start
Provide Coating Material
90
Place Device (package) in Chamber
92
Perform Anti-stiction Layer Coating
94
Complete Coating Process
96
Remove Device from Chamber
98
End

FIG. 14

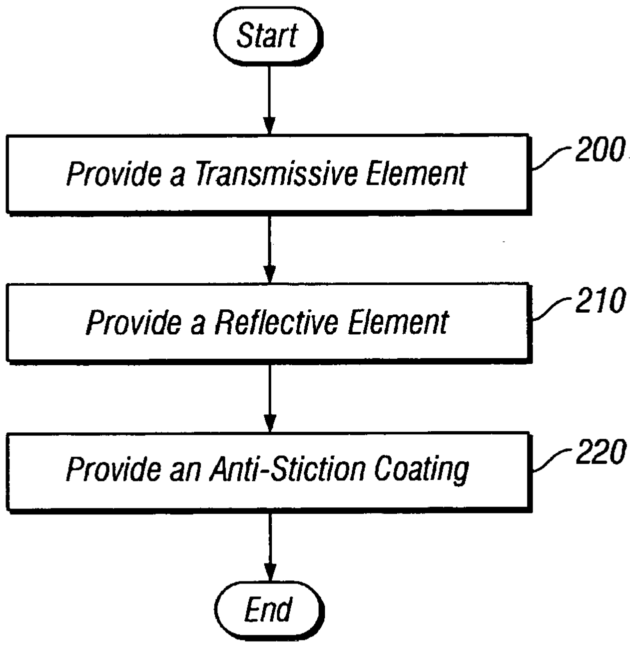
Start
Provide a Transmissive Element
200
Provide a Reflective Element
210
Provide an Anti-Stiction Coating
220
End

FIG. 15

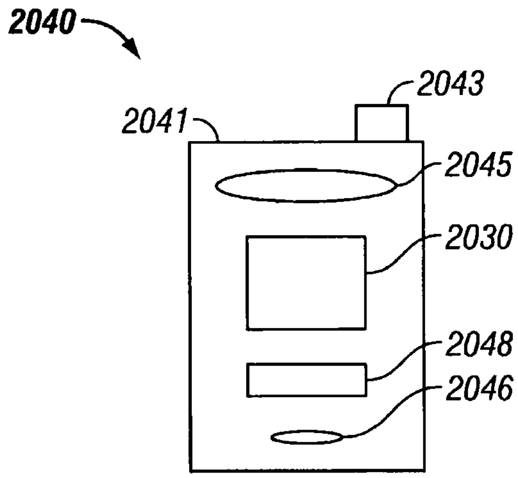

FIG. 16A

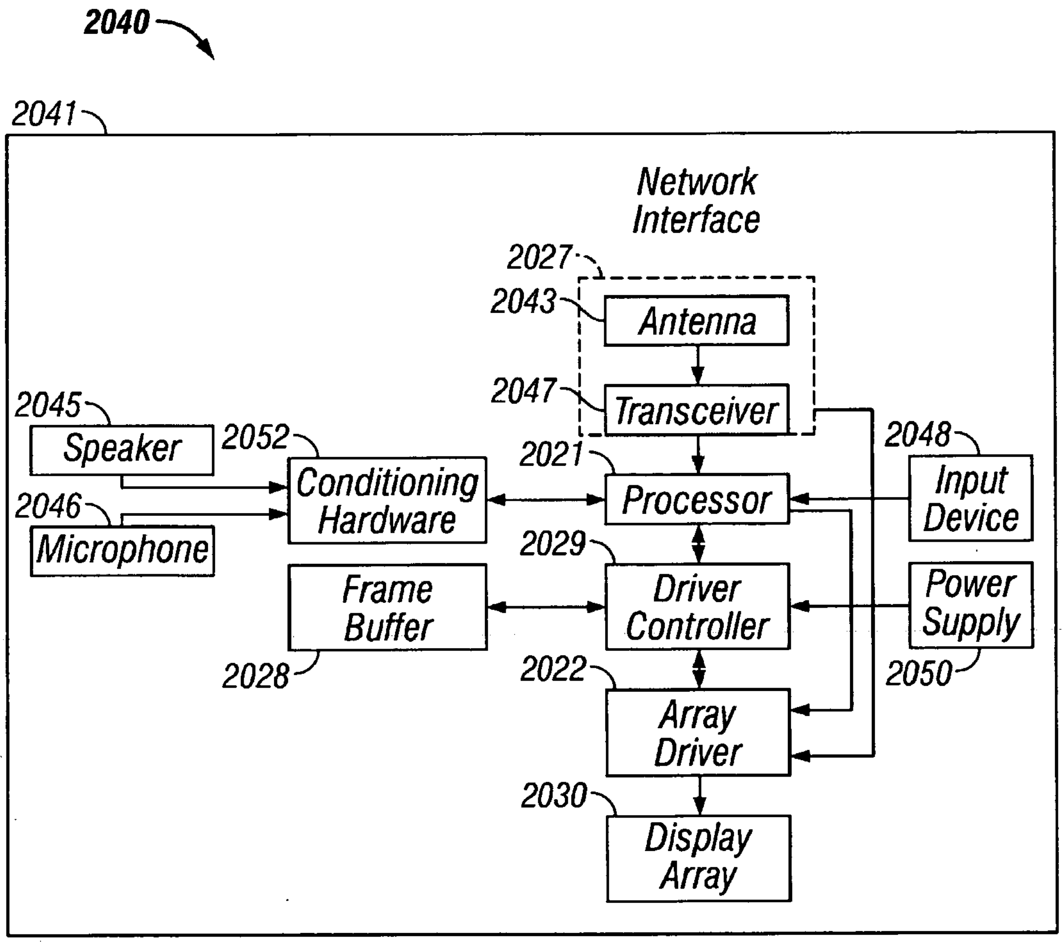

FIG. 16B

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 05 25 5675

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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Y	US 2002/015215 A1 (MILES MARK W) 7 February 2002 (2002-02-07) * paragraphs [0040] - [0042]; figure 1d *	1-34	
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Y	ASHURST W R ET AL: "Vapor phase anti-stiction coatings for MEMS" IEEE Transactions on Device and Materials Reliability IEEE USA, vol. 3, no. 4, December 2003 (2003-12), pages 173-178, XP002359780 ISSN: 1530-4388 * the whole document *	1-34	G02B G01J B81B G02F
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	19 December 2005	Hambach, D

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EUROPEAN SEARCH REPORT

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EP 05 25 5675

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			TECHNICAL FIELDS SEARCHED (IPC)

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The members are as contained in the European Patent Office EDP file on
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